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Comparison of different calculation indexes with dose volume histogram parameters for evaluation of radiation treatment plans in gynecologic malignancies

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► ***Original article***

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ABSTRACT

Background: We aimed to investigate the accordance of Critical Organ Scoring Index (COSI), Conformity Index (CI) and Normal Tissue Complication Probability (NTCP) parameters with Dose Volume Histograms (DVH) used for evaluation of 3 different pelvic radiotherapy plans. ***Materials and Methods:*** Ten gynecologic carcinoma patients who underwent adjuvant radiotherapy were enrolled in this study. Treatment plans were created with conformal treatment planning (3DCRT) and intensity modulated radiation therapy (IMRT) to a total dose of 50.4 Gy in 28 fractions. Initially, volume related dose evaluation was done via DVH. Subsequently, HI, CI, COSI and NTCP for selected normal tissues were calculated for each plan and compared with DVH parameters. Finally, a graphical demonstration was evaluated to see if the results were in accordance with DVH. ***Results:*** CI results were statistically significant in favor of IMRT ($p<0.001$). Rectum V_{40Gy} decreased with 9IMRT compared to 3DCRT and 7IMRT ($p=0.013$ and $p=0.013$). V_{40Gy} for bladder was also lower with 9IMRT compared with 3DCRT and 7IMRT ($p=0.005$ and $p=0.012$). COSI calculations revealed better small intestine protection in IMRT plans similar with DVH ($p=0.005$ and $p=0.022$). Femoral heads were better protected with IMRT plans were better compared to 3DCRT in NTCP calculations ($p=0.002$). Normal tissue protection was worst with 3DCRT via both DVH and COSI evaluations ($p=0.001$ and $p<0.001$ respectively). ***Conclusion:*** Using the indexes in this study to decide the most appropriate plan among multiple treatment plans in gynecologic cancer patients will be timesaving and easier in comparison with evaluating the DVH of every alternative plan.

Keywords: *Gynecological radiotherapy, treatment planning, dosimetric evaluation.*

INTRODUCTION

Endometrial and cervical cancers are amongst the top 4 gynecological malignancies with increasing incidence and mortality [1]. Surgery, followed by adjuvant pelvic radiotherapy (APR) in the presence of risk factors for pelvic and vaginal relapses, is the standard of care in endometrial carcinoma [2,3]. For early stage cervical cancers, radical surgery or definitive radiotherapy are similar in terms of treatment outcome [4]. As in endometrial carcinoma, in the presence of high-risk factors APR following radical hysterectomy is the commonly held treatment approach [5,6]. However, addition of APR after surgery leads to an increase in the frequency and severity of gastrointestinal and genitourinary side effects [7].

An irregularly shaped isodose line covering an irregular tumor volume, as in gynecologic malignancies, can be obtained with intensity

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modulated radiotherapy (IMRT), while the appropriate tolerance doses for adjacent organs at risk (OAR) is maintained [7]. In several studies, a statistically significant reduction in chronic complications regarding gastrointestinal and hematological toxicities with IMRT has been reported [8,9].

The goal of radiation therapy (RT) is to deliver an adequate therapeutic dose to the target volume (TV) while minimizing the risks of normal tissue complications [10]. In order to achieve this, different treatment planning techniques can be used in radiation therapy. The International Commission on Radiation Units and Measures (ICRU- report 83) has defined the evaluation (prescribing, reporting and comparison) of different treatment plans in three levels [11].

Level 1 has been invalidated with recent technological developments in treatment devices and planning. Level 2 recommends volumetric dose evaluation for target volume (TV), organs at risk and normal tissues (NT) [11]. Hence, parameters that determine plan quality such as three-dimensional (3D) isodose distribution, dose volume histograms (DVH), homogeneity index (HI) and conformity index (CI) acquired currency in this level [12]. Level 3 includes radiobiological evaluations such as tumor control probability (TCP) and normal tissue complication probability (NTCP) which are not used in the clinical standard [11].

The most important disadvantage for CI and HI is that these models do not take the overall dosimetric information provided by DVHs into consideration. Consequently, DVHs are still accepted as key indicators of compliance with clinical requirements. Another crucial drawback is the lack of estimations in terms of organs at risk and healthy tissue sparing while evaluating target coverage and conformity, which is a dose limiting issue in radiotherapy.

Choosing the most appropriate plan is a highly subjective process. To pick the best plan, detailed evaluation of DVH and isodose distribution is needed by an experienced and attentive physician [13]. Although several approaches and parameters are suggested to ease and improve this process, none of these models had a widely accepted use in clinical practice [14]. The ideal solution for comparison of different plans is the formation of an index which combines all data and presents these in a simple and quantitative manner [15]. The critical organ scoring index (COSI) is a calculation model derived for this purpose. This index takes both target volume coverage and critical organ doses into consideration. The main advantage of COSI is its discriminative ability for different critical organs [16].

In this study, selected DVH parameters of 3 different radiotherapy treatment plans for endometrium-cervix carcinoma were compared. The accordance of DVH parameters with COSI, CI and NTCP calculations, which were suggested as alternatives for DVH parameters in plan evaluation, was investigated. Additionally, a graphical demonstration which allows easy and rapid evaluation was investigated as an alternative for DVH in comparing multiple treatment plans.

MATERIALS AND METHODS

Patients

Ten patients with gynecological cancer (5 endometrium and 5 cervix), who were treated with adjuvant radiotherapy from April 2014 through September 2016, were enrolled in this study. Median age of patients was 56 (27-75) years. The histologic type, grade, stage and chemotherapy information of the patients enrolled in the study is given in table 1. Planning tomography images of the patients were re-evaluated retrospectively.

Ethical considerations

This study was approved by the Institutional Scientific Research Ethics Committee. All procedures performed were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was waived owing to the retrospective chart review nature of the study.

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Table 1. Demographic features of the patients.

	Endometrium				Cervix			
	Histologic Type	**Grade**	**Stage***	**Chemotherapy**	**Histologic Type**	**Grade**	**Stage***	**Chemotherapy**
Patient 1	Papillary serous	3	IB	6xCP	Adenocarcinoma	2	IIB	Cs
Patient 2	Endometrioid	2	IB	-	Adenosquamous	2	IIA_1	-
Patient 3	Endometrioid	3	IB	-	SCC	2	$IIIC_1$	Cs
Patient 4	Endometrioid	2	II	-	Adenocarcinoma	2	IIA_2	-
Patient 5	Endometrioid	2	$IIIC_1$	Cs + 3xCP	SCC	2	IB_2	-

CP: Adjuvant Carboplatin + Paclitaxel; Cs: Radiotherapy concurrent weekly cisplatin; SCC: Squamous Cell Carcinoma
*Patients were restaging according to the American Joint Committee on Cancer (AJCC) 8th edition.

Simulation and contouring

Patients were scanned in the supine position with full bladder and arms joined over the chest. Axial slices from the upper abdomen through the low perineum were obtained using appropriate immobilization systems and IV contrast on a CT simulator (GE-Lightspeed 64, GE, ABD) with 2.5 mm slice thickness for all patients. The clinical target volume for tumor bed (CTV_1) includes vagina and paravaginal soft tissues ending at the lower border of the obturator fossa as the lowest limit. The clinical target volume for regional lymph nodes (CTV_2) involved common iliac, external iliac, internal iliac, obturator and presacral lymph nodes at the S1-2 level, with the upper border of L5 as the upper limit. A seven mm posterior margin and a 10 mm margin in other directions were added to the CTV_1 to obtain the planning target volume 1 (PTV_1) and a 7 mm margin was added in all directions to CTV_2 for PTV_2. Whole bladder, rectum from anal canal to sigmoid loop, bilateral femoral heads, and small bowel surrounding PTV were contoured as OAR. PTV was called TV in this study. All tissues enclosed in the treatment field other than TV are defined as normal tissues (NT).

Planning

Three different treatment plans using CMS XIO (Version 4.80, Elekta, Stockholm, Sweden) treatment planning system (TPS) were created with different field numbers and angle ranges as 3D conformal (3DCRT), 7 field IMRT (7IMRT) and 9 field IMRT (9IMRT). Gantry angles were 0, 90, 270 and 180º for 3DCRT; 0, 51, 102, 153, 205, 255, 306º for 7IMRT and 20, 60, 100, 140, 180, 220, 260, 300, 340º for 9IMRT.

The treatment schedule was the same for the 3 plans and the total dose was 50.4 Gy in 28 fractions, with a 1.8 Gy fraction dose a day via 18 MV photons for 3DCRT and 6 MV photons for IMRT planning techniques.

Both 3DCRT and IMRT plans were designed to give 98% of the prescribed dose to 95% of the TV. The median dose was also provided as close as possible (± 1 Gy) to the prescribed dose. In all plans, a superposition - convolution calculation algorithm was used and IMRT plans were optimized with a step and shoot technique.

Plan Evaluation

Plan evaluations are carried out 3 steps. The first step consisted of volumetric dose evaluation via DVH. Additionally, dose distributions in transverse, coronal or sagittal planes were controlled visually. In the second step, HI and CI calculations for TV and NTCP and COSI calculations for OAR's were completed. In the last step, CI-COSI and DVH-COSI graphics were evaluated for each organ individually. Consequently, a CI-COSI graphic, including all OAR's for easier and rapid evaluation, was obtained. The equations used for calculation of CI, HI, COSI and NTCP parameters are given below.

For CI calculations, the equation suggested by Paddick *et al.* [17] was used (equation 1):

$$CI = \frac{TV_{PIV}}{PIV} x \frac{TV_{PIV}}{TV} \quad (1)$$

TV_{PIV} Target volume covered by the reference isodose
PIV Volume of reference Isodose
TV Target Volume

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The equation used for HI calculations is shown below (equation 2):

$$HI = \frac{D_{2\%} - D_{98\%}}{D_{50\%}} \quad (2)$$

In this equation $D_{2\%}$, $D_{98\%}$ and $D_{50\%}$ stand for the doses of 2%, 98% and 50% of TV calculated from DVH.

COSI calculations were carried out using the equation below (equation 3):

$$COSI = 1 - \frac{V(OAR)_{>tol}}{TC_V} \quad (3)$$

$V\ (OAR)_{>tol}$ Volume of organ at risk receiving more than a pre-defined tolerance dose

TC_V Volumetric target coverage

For calculation of COSI, tolerance doses were selected as 30 Gy for Small Bowel (SB) and Femoral Heads (FHs), and 40 Gy for Rectum (RCT) and Bladder (BLD). For NT, this value was selected as 25.2 Gy, which is 50% of the prescribed dose. All volumes covered by the selected tolerance doses (V_{30Gy}, V_{40Gy} and $V_{25.2Gy}$) were converted into geometrical shapes in the TPS and these created volumes were used in COSI calculations for OAR evaluations.

In our study, the average of the values of 10 patients in the group was taken for each plan. For bilateral organs, the mean values of left and right were taken as a single OAR volume (FHs for L-R Femoral Heads). For all planning techniques, evaluations were done by developed CI and COSI, using DVH and COSI graphics. Ideal plan values were given in the same graphics. Additionally, NTCP was calculated in critical organ evaluations with different DVH and COSI results.

The model suggested by Lyman allows the estimation of NTCP for an arbitrary partial volume irradiated uniformly to a dose D [18]. This model relies on clinical data for uniform whole organ irradiation. According to Lyman's model, NTCP for uniform irradiation of a fractional organ volume can be given by equations 4-6.

$$NTCP = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{t} e^{-t^2/2}\, dt \quad (4)$$

$$t = \frac{[D - TD_{50}(\upsilon)]}{m * TD_{50}(\upsilon)} \quad (5)$$

m = Parameter describing the slope of NTCP vs. dose

TD_{50} (υ) = the dose for uniform irradiation of the partial volume leading to a 50% probability of complication

$$TD_{50}(V) = \frac{TD_{50}(1)}{V^n} \quad (6)$$

n = Parameter describing the volume dependence.

V = Fraction of reference volume irradiated

TD_{50} (1) = The dose for the reference volume leading to a 50% probability of complication

The n, m, and TD_{50} values of the corresponding OAR as defined by Burman et al. were used for the calculation of NTCP in the TPS [19].

All the parameters used for calculations and end points are shown in table 2.

Statistical analysis

The Statistical Package for Social Sciences version 15.0 (SPSS Inc., LEAD Technologies, 1991/US) was used for statistical analysis. The Friedman test and Wilcoxon signed-rank test were used for comparisons. $P<0.05$ was considered to be significant.

Table 2. Fitting of normal tissue tolerance data on analytic function [19]

Organs at Risk	Reference Volume	n	m	TD_{50}	End Point
Rectum	Whole Organ	0.12	0.15	80	Severe proctitis/necrosis/stenosis/fistula
Bladder	Whole Organ	0.5	0.11	80	Symptomatic bladder contracture and volume loss
Femoral Heads	Whole Organ	0.25	0.12	65	Necrosis
Small Bowel	Whole Organ	0.15	0.16	55	Obstruction/Perforation

n: Parameter describing the volume dependence; m: Parameter describing the slope of NTCP vs. dose; TD_{50}: The dose to partial volume leading to a 50% probability of complication.

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RESULTS

In total, 30 treatment plans with 3 different techniques for each patient were obtained. Isodose distributions in the axial slices confirmed that 95% of the TV was enclosed in 98% of the prescribed dose (49,39Gy). CI, HI data and p values from the plans are shown in table 3. HI values were similar in all treatment plans. CI values were significantly better in favor of IMRT plans (p<0.001). Although the 9IMRT plan was better, there was no statistically significant difference between two IMRT plans (p=0.219).

Table 3. The CI and HI minimum, maximum, mean values and standard deviations for 3DCRT, 7IMRT and 9IMRT treatment planning techniques

	3DCRT	7IMRT	9IMRT	P value
CI	0.49 (±0.01)	0.82 (±0.02)	0.84 (±0.04)	<0.001
HI	0.10 (±0.01)	0.10 (±0.01)	0.10 (±0.01)	0.43

CI: conformity index, HI: homogeneity index, 3DCRT: 3D conformal radiotherapy, IMRT: intensity modulated radiotherapy Values are expressed as mean value (± SD)

Rectum

The total rectum mean volume was 97.4cc, and the mean COSI and DVH values with all 3 techniques for rectum V_{40Gy} can be seen in table 4. According to DVH evaluation, 9 IMRT was found to provide the best rectum protection (p=0.002). Rectum V_{40Gy} decreased in 9IMRT plans compared to both 3DCRT and 7IMRT by 33% and 31% respectively (p=0.013 and p=0.013). Only a 3.1% reduction was obtained with 7IMRT compared to 3DCRT (p=0.059). In terms of COSI results; 9IMRT was significantly better compared to 3DCRT (p=0.041), where the difference with 7IMRT was not statistically significant (p=0.317). Likewise, 3DCRT and 7IMRT were not significantly different (p=0.072). The values closest to an ideal plan were obtained with the 9IMRT plan, according to both DVH and COSI evaluations (figure 1). The comparison of COSI-CI values for rectum with the ideal plan is shown in figure 1a and 1b respectively.

Table 4. DVH and COSI values with standard deviations in 3DCRT, 7IMRT and 9IMRT plans for rectum and bladder V_{40Gy}, small intestine and femoral heads V_{30Gy} and normal tissue V25.2Gy

	DVH (cc)				COSI (cc)			
OARs and mean volumes(cc)	3DCRT	7IMRT	9IMRT	p value	3DCRT	7IMRT	9IMRT	p value
Rectum (97cc)	76.2 (±21)	73.6 (±18)	50.7 (±15)	0.002	0.917 (±0.01)	0.926 (±0.01)	0.936 (±0.01)	0.091
Bladder (267cc)	218.9 (±88)	122.1 (±50.4)	113.7 (±46)	<0.001	0.778 (±0.09)	0.868 (±0.05)	0.875 (±0.04)	<0.001
Small Bowel (1614cc)	679.5 (±56)	526.3 (±131)	552.8 (±112)	0.025	0.310 (±0.10)	0.526 (±0.09)	0.494 (±0.09)	0.002
Femoral Heads (42cc)	31.5 (±6)	22.1 (±4)	20.3 (±5)	<0.001	0.964 (±0.004)	0.978 (±0.003)	0.974 (±0.01)	<0.001
Normal Tissue (13121cc)	6664.7 (±829)	5137.6 (±550)	5104.3 (±543)	0.001	0.493 (±0.02)	0.595 (±0.03)	0.606 (±0.04)	<0.001

Values are expressed as mean volume (± SD). HI: homogeneity index, 3DCRT: 3D conformal radiotherapy, IMRT: intensity modulated radiotherapy; OARs: Organs at Risk;

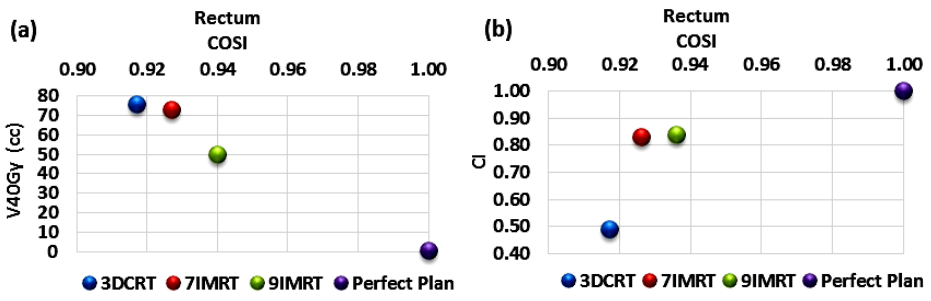

Figure 1. (a) Critical Organ Scoring Index (COSI) - V_{40Gy} (cc) and **(b)** Critical Organ Scoring Index (COSI) - Conformity Index (CI) values of Rectum for 3 different treatment plans and perfect plan.

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Bladder

The mean total bladder volume was 267.5 cc, and the mean COSI and DVH values with all 3 techniques for bladder V_{40Gy} can be seen in table 4. According to DVH evaluation 9 IMRT was found to provide the best bladder protection ($p<0.001$). The V_{40Gy} value was decreased compared to both 3DCRT and 7IMRT plans by 48% and 6% ($p=0.005$ and $p=0.012$ respectively). 3DCRT provided 44% lower bladder protection compared to 7IMRT plans ($p=0.005$). With COSI evaluations, worse bladder protection was seen with 3DCRT ($p<0.001$). COSI calculations were found to be similar in 9IMRT and 7IMRT plans ($p=0.083$). A comparison of COSI-DVH and COSI-CI values for a bladder with an ideal plan is plotted in figure 2a and 2b respectively.

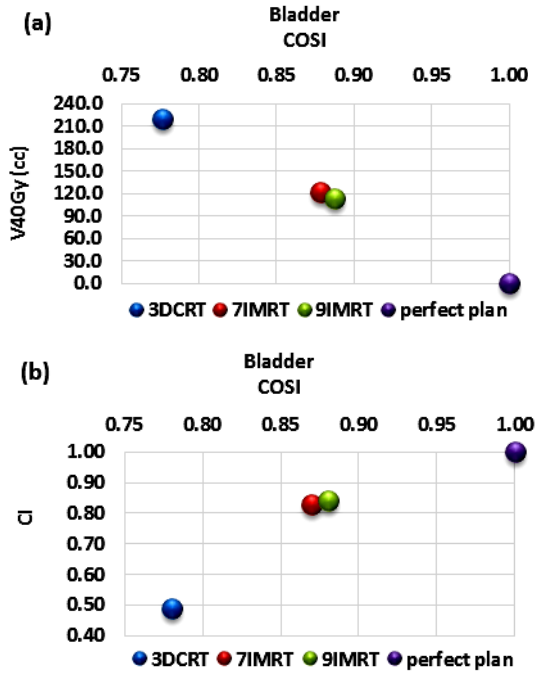

Figure 2. (a) Critical Organ Scoring Index (COSI) - V_{40Gy} (cc) and **(b)** Critical Organ Scoring Index (COSI) - Conformity Index (CI) values of Bladder for 3 different treatment plans and perfect plan.

Small bowel

The small bowel mean volume was 1614.7 cc, and the mean COSI and DVH values with all 3 techniques for small bowel V_{30Gy} can be seen in table 4. DVH calculations showed that 3DCRT provides the least small intestine protection ($p=0.025$). The best results for V_{30Gy} were obtained with 7IMRT, and the decrease in small bowel volume compared to 3DCRT was 22.5% ($p=0.007$). The volume reduction compared to 9IMRT was 4.7% ($p=0.95$). In line with DVH results, COSI calculations also revealed better protection with 7 and 9IMRT plans ($p=0.005$ and $p=0.022$ respectively). 7IMRT was closer to the ideal plan in DVH and COSI evaluations in figure 3a; however, the difference between the two IMRT plans was not statistically significant ($p=0.95$ and $p=0.083$ with DVH and COSI respectively). A comparison of the COSI-CI values with an ideal plan is seen in figure 3b.

Figure 3. (a) Critical Organ Scoring Index (COSI) – V_{30Gy} (cc) and **(b)** Critical Organ Scoring Index (COSI) - Conformity Index (CI) values of Small Bowel for 3 different treatment plans and perfect plan.

Femoral heads

The DVH and COSI mean values of V_{30Gy} for femoral heads with all 3 plans are shown in table 4. According to DVH evaluations, the decrease in V_{30Gy} volume with the 9IMRT plan compared to 7IMRT was 8%, but it was 29.8% with 7IMRT compared to 3DCRT ($p=0.007$ and $p=0.005$ respectively). No statistically significant difference was found between the two IMRT

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plans with COSI evaluations (p=0.083). However, both IMRT plans were significantly better compared to 3DCRT (p=0.008 and p=0.006 for 9 and 7 IMRT plans respectively). DVH and CI values evaluated with COSI are presented in figures 4a and b, where a comparison with ideal plans can be seen. V_{30Gy} for femoral heads was better with the 9IMRT plan, where COSI calculations indicated 7IMRT as the best plan. In terms of V_{30Gy}, which is low as a tolerance dose definition for femoral heads, 9IMRT and 7IMRT were similar (p=1). The maximum doses to femoral heads were calculated as 40.8 Gy and 40.3 Gy with 7IMRT and 9IMRT plans respectively (p=0.059).

When evaluated with NTCP, the difference between 3DCRT and IMRT plans in terms of rectum, bladder, small bowel and femoral heads was statistically significant (p<0.001); however, the difference between the two IMRT plans was not statistically significant (p=0.47). NTCP values for rectum, bladder, small bowel and femoral heads with standard deviations and p values are shown in table 5.

Normal tissue

DVH and COSI mean values of $V_{25.2Gy}$ for normal tissues with all 3 plans are shown in table 4. According to DVH and COSI evaluations, the least protection for normal tissues was obtained with the 3DCRT plan (p=0.001 and p<0.001 respectively). NT values were reduced by 23.4% with 9IMRT plans compared to 3DCRT. 9IMRT plans provided the best protection with both DVH and COSI evaluations, but the difference between 9 and 7 IMRT was not statistically significant (p=0.57 and p=0.075 respectively). Ideal plan comparisons of COSI-DVH and COSI-CI values are shown in figure 5a and 5b.

Figure 6 provides a simple and pellucid graphic with CI values of 3 different plans and COSI values of all critical organs at a glance.

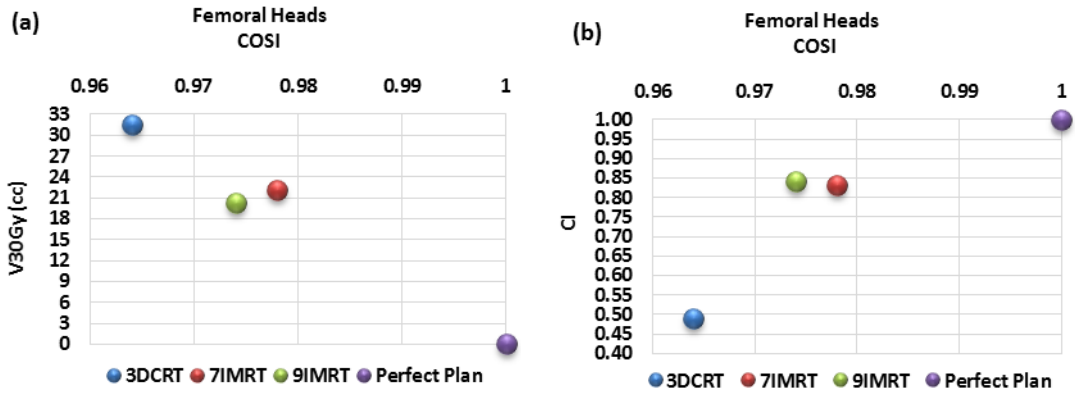

Figure 4. (a) Critical Organ Scoring Index (COSI) – V_{30Gy} (cc) and **(b)** Critical Organ Scoring Index (COSI) - Conformity Index (CI) values of Femoral Heads for 3 different treatment plans and perfect plan.

Table 5. NTCP values of 3 different plans

	3DCRT	7IMRT	9IMRT	P value
Rectum	49.81(±10.62)	0.20(±0.02)	0.19(±0.02)	0.001
Bladder	0.03 (±0.004)	0.01(±0.002)	0.01(±0.002)	<0.001
Small bowel	14.38(±8.57)	2.01(±0.88)	2.27(±0.97)	0.001
Femoral Heads	0.03(±0.004)	0.01(±0.004)	0.01(±0.004)	<0.001

Values are expressed as mean value (± SD). 3DCRT: 3D conformal radiotherapy, IMRT: intensity modulated radiotherapy; OARs: Organs at Risk;

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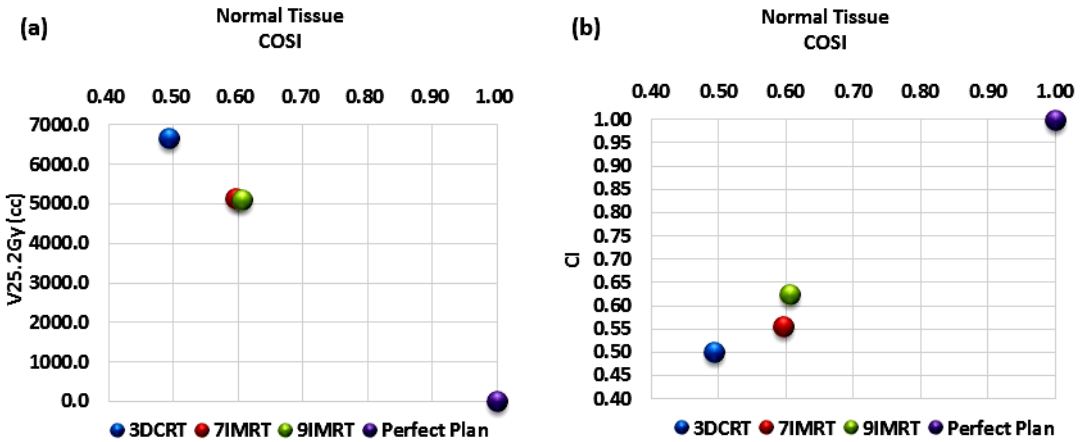

Figure 5. (a) Critical Organ Scoring Index (COSI) – $V_{25.2Gy}$ (cc) and **(b)** Critical Organ Scoring Index (COSI) – Conformity Index (CI) values of Normal Tissue for 3 different treatment plans and perfect plan.

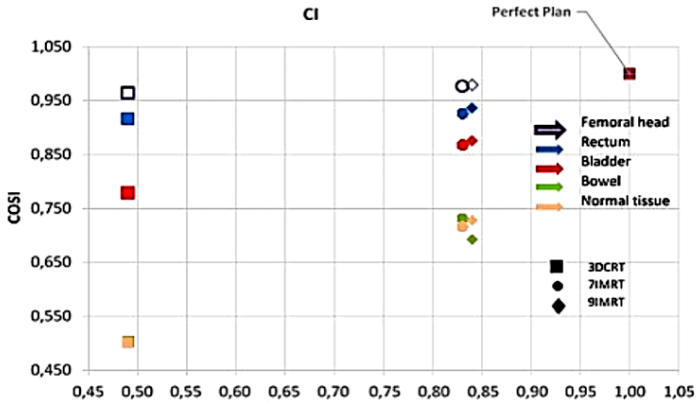

Figure 6. Conformity Index (CI) – Critical Organ Scoring Index (COSI) values of all organs at risk and normal tissue for 3 different treatment plans and perfect plan.

DISCUSSION

An optimal radiotherapy plan aims to cover the tumor volume adequately with the prescribed isodose line, while in the meantime avoiding healthy tissues as much possible. This requires creating multiple plans with different techniques and different angles for each patient. Plan evaluation slice by slice in terms of isodose and/or DVH assessment may help to run through the whole plan. Although DVH has the widest range of utilization currently as a comparison index for TV between multiple plans it is inadequate due to a lack of spatial information [16]. A safe and easy model considering the target volume with OAR doses is needed to compare different plans accurately. HI and CI have currently widespread utilization in multiple plan evaluations in terms of TV. Feuvret *et al*. reviewed different CI calculations suggested to date and reported that only the CI calculation suggested by Van't Riet et al. ($CI_{PADDICK}$), considered both the target volume and OAR [17]. However, this formula is also inadequate because it does not include differences between organs [12]. Additionally, data demonstrating the correlation between clinic and CI models are scarce to date [14]. All above mentioned drawbacks created a need for a new comparative index. Menhel *et al*. developed the COSI formula, which has a discriminative ability for different critical organs [16]. The closer the COSI value to 1, the better indication of OAR protection; however, this result does not provide any information about conformity. In our study the TV dose was

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evaluated with $CI_{PADDICK}$ [17]. To detect the suitable plan for both TV and OAR we used COSI – CI graphics. After evaluation of TV and a having determined critical organs with COSI - CI graphics, the closest technique to the ideal plan seems to be 9IMRT for TV, bladder, rectum, femoral head and normal tissue, but 7IMRT for the small bowel.

In radiation treatment, DVHs provide a graphical demonstration of dosimetric data about TV and OARs and currently represent the most common tool to compare different treatment plans. However, it is all but impossible for the radiation oncologist to evaluate all the relative data obtained from alternative plans sufficiently and accurately. As there is no way to see all the DVH data overlapped to provide a comparison at a glance, we need another convenient constant [16]. We created COSI-DVH graphics in our study to detect the consistence among the parameters used for critical organ evaluation.

Heron and colleagues found a 36%, 66% and 52% decrease in volume exposed to 30 Gy or more for the bladder, rectum and small bowel, respectively, after comparison of 3DCRT and 7IMRT in cervix carcinoma patients [20]. In their study Roeske et al. showed that rectum and bladder volumes over 25 Gy dose, or small bowel volumes up to 30 Gy dose, are significantly lower with 9IMRT compared to the 4 field box technique (p=0.0005, p=0.0002, and p=0.0005 respectively) [21]. In our study, according to DVH results, V_{40} for rectum and bladder, V_{30} for small bowel and femoral heads were better with IMRT plans as compared to 3DCRT. 9IMRT provided a significantly better protection than 7 IMRT plans for rectum, bladder and femoral heads. 7IMRT and 9IMRT was significantly better in small bowel and normal tissue protection, respectively, but both IMRT plans were not statistically different from each other.

Menhel *et al.* compared the 3DCRT and IMRT plans for many tumor regions other than pelvic malignancies with COSI-CI_{RTOG} graphics [16]. They showed that in cases where there is a discrepancy, the COSI-CI representation is the more accurate one, in several cases indicating that the 3D plan is actually superior to the IMRT plan. They concluded that the main advantage of that methodology was the ability to simultaneously compare multiple plans and multiple critical structures.

In COSI-CI and COSI-DVH graphics, discrepancies were evaluated in a simple 2D manner, quickly and accurately. When IMRT plans were evaluated with each other, every statistically significant DVH value was not significant with COSI calculation. The COSI model was insufficient to show the difference between IMRT plans, while it was able to detect the significance between IMRT plans and 3DCRT. COSI-DVH graphics seem to be more useful in OAR evaluations as compared to COSI-CI graphics, but the combined COSI-CI graphic gives an opportunity to compare both TV and all OAR values. This is a distinctive study on gynecologic tumor patients which will lead the way for evaluations in considering patient requirements in radiotherapy plan choices.

Additionally, the NTCP values for rectum, bladder, small bowel and femoral heads have confirmed the difference between 3DCRT and IMRT plans in favor of IMRT. However, the difference between the two IMRT plans were not statistically significant. This result is attributed to low prescription doses to cause complications in OARs. This result lead us to the conclusion that NTCP will be a more effective tool for plan comparison in high dose IMRT treatments.

CONCLUSION

In pelvic radiotherapy, 9IMRT seems to be the best plan for both TV and critical organs. It is within the physician's initiative to use 7IMRT alternatively for patients who are predicted to encounter small bowel problems during their treatment. In our opinion, additional different criteria providing easier and rapid multiple plan evaluation can be created with larger studies, including different treatment plans, dose schedules and treatment regions.

***Conflicts of interest*:** *Declared none.*

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